Space Weather Technical Forecast

Issued on Thursday 10 October 2024 at 13:13 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: CME inbound: G2 Expected, Slight Chance G4 in next 24 hours. S3 Likely. Now reducing risk of further R3s.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Activity measured at GOES16 and 18 has been at High levels, with an X1.4 peaking at 09/1547UTC, an M7.7 flare at 09/2312UTC and an M1.9 at 10/1159UTC - all from AR3842.

There are seven numbered sunspot regions on the visible disc at present, although this number is likely to be in a state of flux due to emerging regions, east limb arrivals and western solar horizon departures. The recent most active group, AR3842, is now presenting as its trailing spots only, and some aspects of this group have been persisted on the limb as a result to obtain a more realistic of X-ray flare risk (e.g. Zurich class).

In the east, two regions attained numbers in the period, firstly the rapidly-growing AR3854 in the southeast, which emerged and soon reached Zurich Dsi complexity with a spreading tendency taking over as the period evolved. In the north, a small unipolar group was also numbered AR3853. AR3849 near centre disc showed consolidation and areal decay throughout its constituent spots, while AR3850 - to its immediate west - was unchanged.

AR3848 in the northwest still comprised one main penumbral spot, with candidates for tenuous Mt Wilson deltas around its southern and southeastern periphery, which otherwise consisted of numerous small dispersed pores and spots. Finally, in the far southeast, there are signs of a small bipolar group emerging from plage.

A Coronal Mass Ejection (CME) was seen leaving the Sun in association with the X1.4 flare from AR3842. This has been modelled as passing significantly ahead of the Earth and plays no part in the forecast. A second CME visible heading apparently northeast on coronagraphs into the current UTC day has been determined to be far-sided, again to no effect at Earth. No new Earth-bound CMEs were therefore in evidence.

Solar Wind / Geomagnetic Activity: The solar wind measured at L1 by ACE and DSCOVR showed a decline towards a slow regime in the wake of recent CME and perhaps also CH78 fast wind influence.

The solar wind speed showed a slow decline from near 450km/s to around 400km/s by the period's end (with lower discontinuities considered to be artifacts at ACE measurements). The

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solar wind density was within background levels of single figures ppcc, as was the IMF with a peak of 7nT. The north-south component varied about zero, with a range of +/-5nT. The phi angle was mostly positive (away from the Sun), but near-neutral for a time early in the current UTC morning.

The net result of the above solar wind measures was for provisionally Quiet to Unsettled geomagnetic activity, peaking with a Kp of '3o' in the 12-15UTC interval.

Energetic Particles / Solar Radiation: High energy proton flux observed by GOES18 has continued its response to the X1.8 flare on 09 October. 10MeV peaked at 1115pfu at 10/0325UTC and are showing a very gradual downward trend. 100MeV commenced their downward tendency prior to this reporting period, and peaked at 0.8pfu at the start of the 24-hour window.

High energy electron flux (greater than 2MeV) observed by GOES16 has generally been Moderate, peaking at 363pfu at 09/1800UTC. The associated 24-hour fluence was below the Active threshold. No 24-hour integrated fluence figure is available for the period, but the trend is flat and an approximate calculation from estimating using flux graphs yields ~1e7pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: The chances of further R3s reduce in the period as AR3842 leaves the disc. R1s remain Likely given developments on the disc; their complexity; and up to four arrivals over the eastern limb to round out the current UTC working week.

Solar Wind / Geomagnetic Activity: There is now one CME in the forecast: the X1.8 flare and filament eruption early on 09 Oct from the vicinity of AR3848. This is due into the current UTC evening - G2 Moderate geomagnetic storm is Expected and there is a Slight Chance of activity as high as G4 Severe into Friday 11 October. The effects should then wane to Quiet over the UTC weekend, with a late Slight Chance of G1 should a fast wind materialise from a minor following coronal hole.

Energetic Particles / Solar Radiation: High energy proton flux at GOES18 is Likely to briefly return to S3 Major solar radiation storm levels under the influence of the inbound CME, gradually waning from here to leave a Slight Chance of S3 by the UTC weekend and a Chance of S1 by the end of the four days - still slightly above the residual risk for the disc.

High energy electron flux is soon expected to decline from Moderate under the influence of the CME. There is an eventual Slight Chance of recovery over the UTC weekend before any fast wind arrives.

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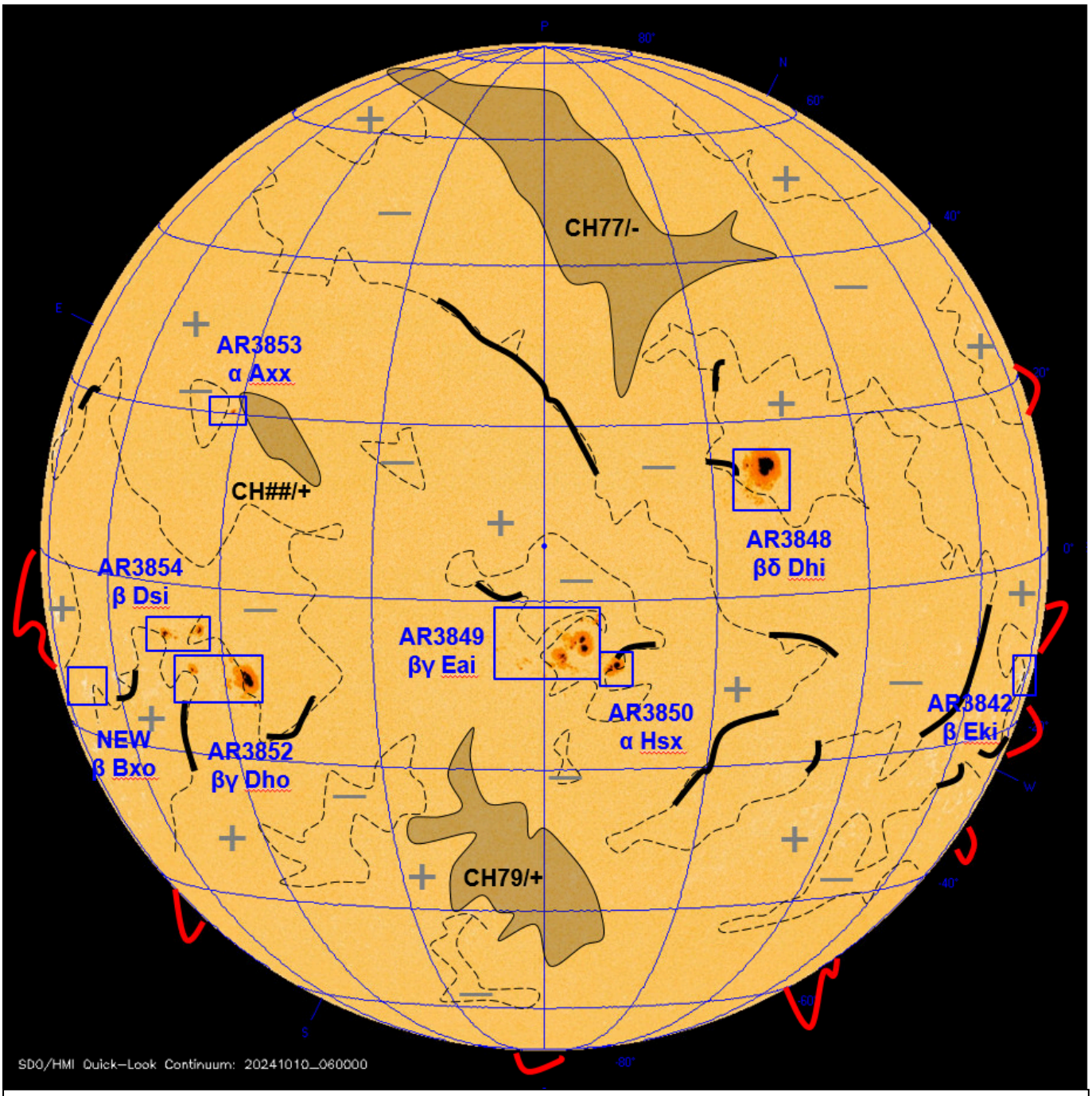
Figure 1:



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms

There is one CME in the forecast, that from the X1.8 flare and filament eruption early on 09 Oct from the vicinity of AR3848. This carries a most likely arrival time from MOSWOC Enlil modelling of early UTC evening of the current UTC day, Thursday 10 October. MOSWOC Enlil's background field is relatively accurate at present, and the deterministic run is felt to offer reasonable guidance as to the expected onset time, with the CME potentially increasing windspeeds to around 700km/s. It should be noted that the accompanying ensemble is showing 3-hourly spaced discretised arrivals through the second half of the UTC day, and the above run is relatively centrally-placed (as well as being generated from the preferred CME ejecta cone figures). The uncertainties in this CME are almost exclusively surrounding the 'when' rather than 'if' as to Earth-based effects - given the CME's central emission location and the parameters obtained from fits.

There is a second, much more minor factor in the four-day forecast - a potential coronal hole fast wind late day four. The presence of this is not assured, with Earth potentially 'threading the needle' between northern and southern hemipshere features. CH79/+ in the south has retreated pole-ward compared to last rotation and appears more tenuous, and therefore any connection with Earth is likely to be weak, with any fast wind approaching 450km/s. Alternatively, CH77/- also stands a chance of connecting around the same time, however its apparent greater intensity (versus CH79/+ from e.g. AIA211 imagery) will be mitigated against by its unfavoured polarity.

Initial Quiet-Unsettled activity is Expected to give way to G2 Moderate storm conditions in the UTC evening of the current day, with a Chance of G3. The ensuing magnetic cloud should continue into the following UTC day, with a Slight Chance of intervals peaking at G4 Severe storm. Beyond this, activity should wane into the start of the UTC weekend to see Quiet conditions restored by Sunday 13 October, with a late Slight Chance of G1 should either of the coronal holes' fast winds impinge on Earth.

Geomagnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	**G1 to G2**	No	95	95	60	5
Strong	**G3**	No	40	50	10	1
Severe	**G4**	No	10	20	1	1
Extreme	**G5**	No	1	5	1	1

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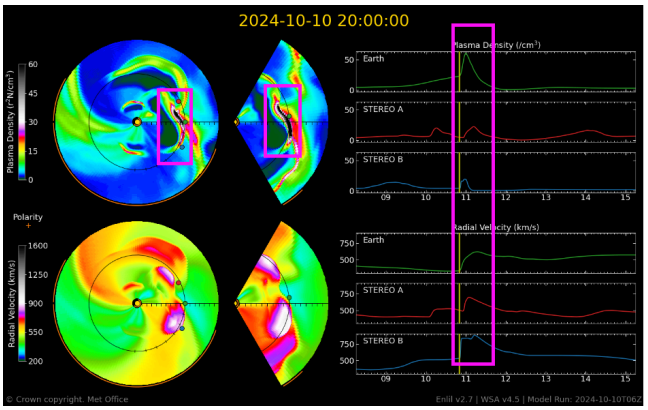
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R⊙ (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed (km/s)	Estimated Arrival Time (UTC)	Comments
09/05:00	Full	AR3848	7W12N	1270	Into UTC evening of 10 October	High confidence for CME to reach Earth but lower confidence for arrival time.

Figure 2: Latest MOSWOC Enlil run and ensemble (badge time 10/0600UTC) showing the inbound X1.8-associated CME boxed in magenta. The simulation is paused around the 1AU crossing time, i.e. early in the current UTC evening.



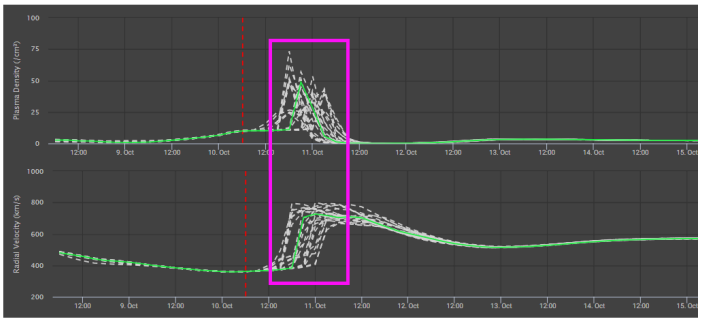


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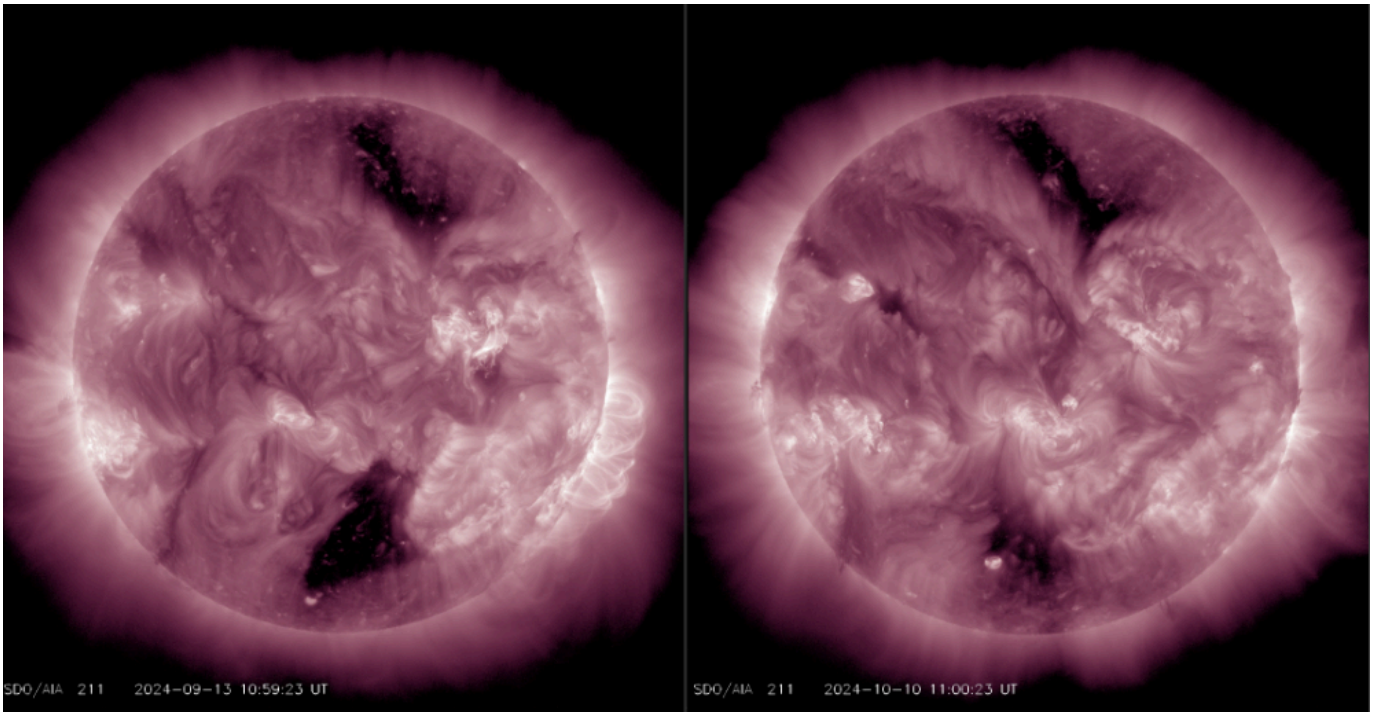
Figure 3: Coronal hole appearances from last rotation (13 September) versus the current time, showing a relative retreat of the southern solar hemisphere CH79/+ between passes.



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Radio Blackouts - X-Ray Flares

The number of sunspots on the Earth-facing side of the disc is currently in a state of flux. The recent very active sunspot region AR3842 is now gradually withdrawing over the western solar horizon - this group has been responsible for numerous X-class flares including the X9.0 on 03 October - the largest of the current solar cycle. Going some way towards potentially mitigating against this loss, are the Carrington locations for up to four returning regions due over the eastern solar horizon inside 48 hours' time. Added to these factors is the consideration of recently emerging sunspot regions in the eastern hemisphere in the form of AR3854 (and to a lesser extent AR3853), perhaps also a new region further southeast (currently an unnumbered Zurich 'Bxo'-like group).

All considered, the risks of further significant flares should very gradually decrease in the coming 24-hour period as AR3842 fully rotates off the disc and the chances of events extending to the upper corona from beyond the limb become lower. The risk sources for further flares are then more well-spread across the disc: AR3848 has the history of such activity in the northwest; AR3849 is decaying (but is in a prone location for CMEs); and the southeast cluster of AR3852 and AR3854 is showing a growth trend.

X-Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 (M Class)	Yes	75	65	60	60
Very Active	R3-R5 (X Class)	Yes	25	15	10	10

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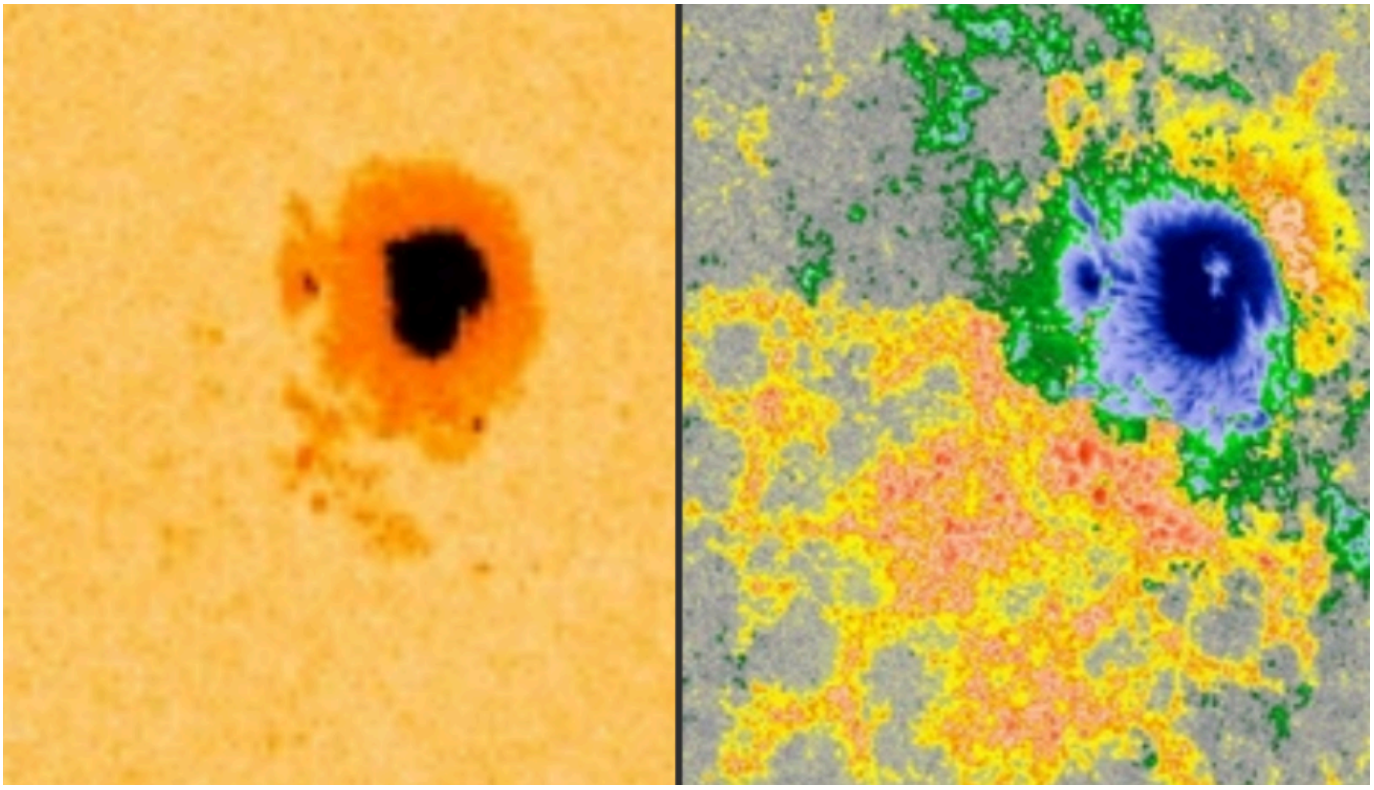
Figure 4: HMIIF and HMIBC imagery of AR3848 at 10/1100UTC, showing (tenuous) candidates for minor Mt Wilson delta spots on the southeastern boundary of the main penumbral spot.



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Solar Radiation Storms (High Energy Protons)

High energy proton flux at GOES18 remains near the S2/S3 boundary in the wake of the combined X1.8 and filament eruption on 09 Oct from the vicinity of AR3848 in the northwestern quadrant. This showed a relatively hard spectral response, however 50MeV and 100MeV traces are now nearing background, with the 100MeV having peaked at 4pfu around UTC dawn on 09 October. The 10MeV response has proven much more sustained, and it is likely to be further bolstered by the inbound CME sweeping up protons in the interplanetary environment. This is likely to extend the risk of a brief return to S3 in the current UTC day, and perhaps early on day two, Friday 11 October.

The risks of S-scale are therefore greatly increased from raw values due to the 'snowplough-like' effect described above, but also given the ongoing S2/3 boundary enhancement, i.e. the high residual counts. AR3848 remains on the disc, although perhaps devoid of its surrounding filaments as a potential source of future activity. Account must also be taken of AR3842's gradual retreat around the far side.

Overall, S3 is Likely in the next 24 hours, falling to a Slight Chance by the UTC weekend. S1 is Expected at first, gradually waning to a Chance by the end of the coming UTC weekend.

Radiation Storms	**Level** ($cm^{-2}sr^{-1}s^{-1}$)	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ S1**	Yes	100	95	60	30
Very Active	**≥ S3 ***	Yes	70	60	20	5
* S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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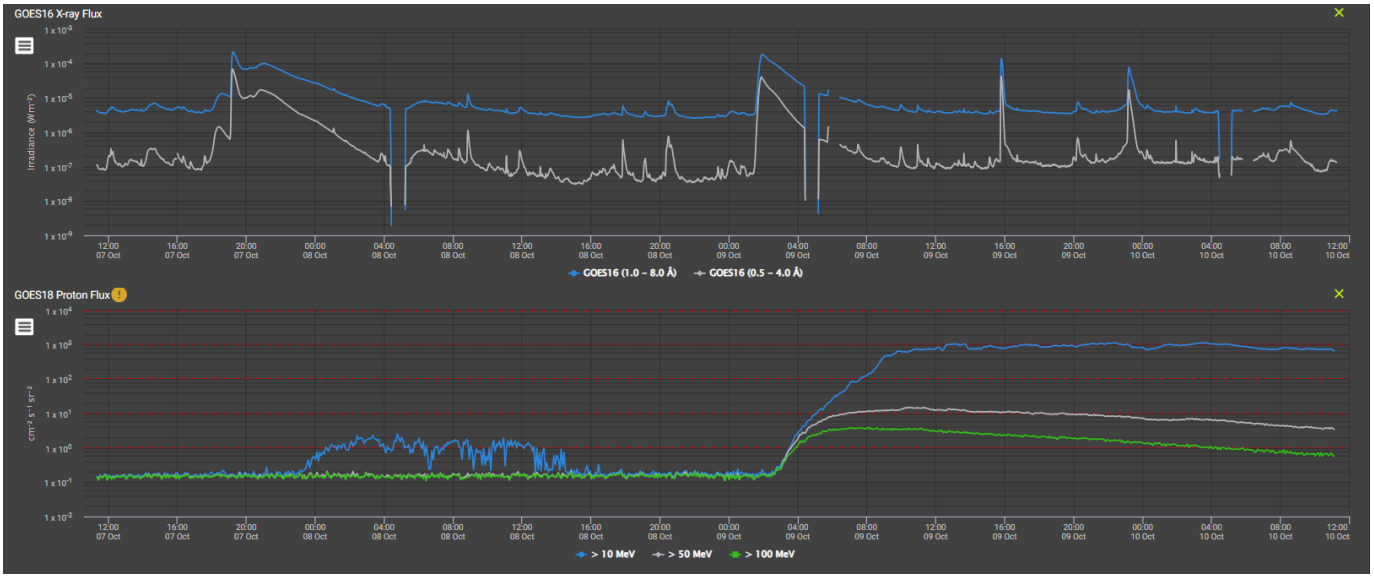
Figure 5: Past 72 hours in GOES16 X-rays (top) and GOES18 proton flux (bottom). Note the much harder spectral response from the Ar3848-related X1.8 flare versus the earlier similarly-sized (flare) event from AR3842.



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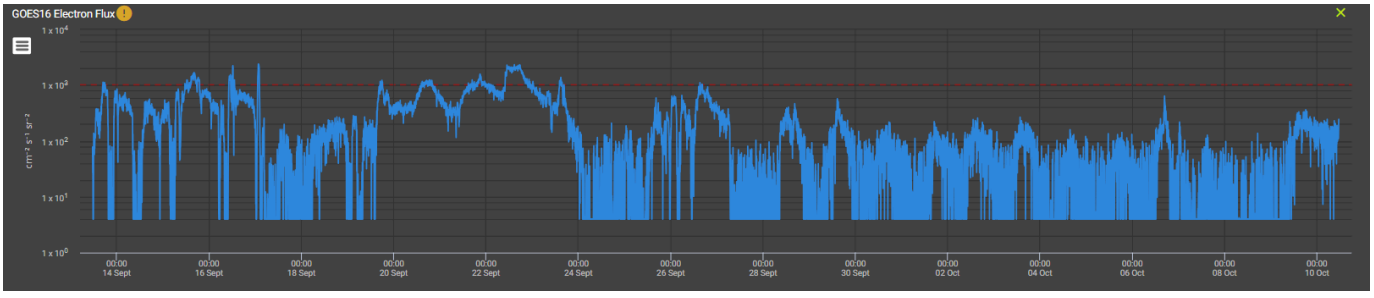
High Energy Electrons (≥ 2MeV)

High energy electron flux (greater than 2MeV) is currently showing a diurnal oscillation peaking at Moderate at GEO. This is Expected to be strongly attenuated later in the current UTC day as the inbound CME heavily compresses radiation belts. Recovery is likely to be slow given the expected magnitude of the event, however there may be a window of opportunity for Active 24-hour electron fluence to be realised over the UTC weekend before any fast wind from CH79/+ (or perhaps CH77/-) takes effect.

There is a rising Slight Chance of Active 24-hour integrated fluence, probably peaking later in the UTC weekend given the forecast described above. MOSWOC REFM is not considered useful in this situation given the utter dominance of a large CME early in its evolution, and the limited forecast horizon of 72 hours for REFM when considering any effects from the fast wind.

GEO Electron Environment	Level ($cm^{-2}sr^{-1}$ day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ 1×10^{8}	No	1	1	5	20
Very Active	≥ 2 MeV ≥ 1×10^{9}	No	1	1	1	1

Figure 6: Past rotation in high energy electron flux at GOES16, showing dissimilarity at the present time versus 27 days ago. These differences will only amplify under the influence of the inbound X1.8 CME and then the changed character of any minor ensuing coronal holes' fast winds.



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